

EXPERIMENTAL STUDY OF INTERACTIONS OF
ELEMENTARY PARTICLES AT HIGH ENERGY

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The thesis presented here covers four different topics (see below) representing my main physics interests since 1962. I thought it to be useful to give a fairly detailed account of each experiment starting with the proposal, then describing the technical efforts and finally giving the results. The first two experiments were done at the Lund 1.2 GeV electron synchrotron, the third at the Hamburg 7.5 GeV electron synchrotron (DESY) and the fourth at the CERN 28x28 GeV² intersecting storage rings.

- I. Photoproduction of neutral pi-mesons on hydrogen (papers 1-9).
- II. A study of the Bremsstrahlung spectrum from the Lund electron synchrotron (papers 10-12).
- III. Small angle scattering of high energy photons on heavy nuclei (Delbrück scattering and photon splitting)(papers 13-16).
- IV. Inclusive particle production at large angles measured at the CERN ISR (papers 17-24).

The dissertation is based on the following papers:

1. Vidicon development for the Lund synchrotron, CERN 64-30, 105 (together with G. von Dardel)
2. Status report on the Lund vidicon system, IEEE NS-12, 78 (1965) (together with G. von Dardel and S. Henriksson)
3. Characteristics of the Lund vidicon system, Lund H6503
4. A vidicon system for the automatic recording of spark chamber events, Nucl. Instr. Meth. 54 (1967) (together with T. Kivikas)
5. Status report on the π^0 photoproduction experiment, LUSY 6804 (together with G. von Dardel, A. Järund and C. Larsson)
6. Electronics developed for the π^0 experiment, LUSY 6807 (together with D. Korder)
7. A beam monitoring system used at the Lund electron synchrotron, LUSY 7001 (together with D. Korder and C. Larsson)
8. Calibration of a lead-glass Cerenkov counter, LUSY 7008 (together with C. Larsson)
9. Preliminary results on the differential cross section of the π^0 -photoproduction on hydrogen, The Conf. in Physics, Lund 1972 (together with S. Almed, G. von Dardel, L. Jönsson, B. Lörstad, J. Palmer, R. Petersen and L. Svensson)
10. Report on the development of a pair spectrometer, LUSY 6702 (together with P. Zimmerman)
11. A scaler-computer interface, LUSY 6806 (together with L. Jönsson)



12. Preliminary results of the Bremsstrahlung spectrum from the Lund electron synchrotron using a pair spectrometer, LUSY 6808
13. Messung des Wirkungsquerschnittes für Delbrück-Streuung bei hohen Energien und kleinen Winkeln, DESY proposal (1970) (together with L. Jönsson, H.D. Schulz, H.J. Willutzki, G.G. Winter and M. Wong)
14. Monte-Carlo generation of multiple scattering of particles, CERN program library (1972) (together with L.Jönsson)
15. Description of a pair spectrometer used to study the small angle scattering of high energy photons, LUSY 7209 (together with L.Jönsson)
16. Small angle scattering of high energy photons on heavy nuclei (Delbrück scattering and photon splitting), preprint 1972 (together with L. Jönsson, J. Prünster, H.D. Schulz, H.J. Willutzki and G.G. Winter), LUSY 7208
17. A survey of multiple particle production in nucleon-nucleon collisions from cosmic ray physics, LUSY 6809
18. Particle production at large angles at the ISR, CERN-ISRC 70-32 (The Scandinavian ISR-Collaboration)
19. Search for quarks in the British-Scandinavian large angle spectrometer, CERN-ISRC 71-9 (The British-Scandinavian ISR Collaboration)
20. The wide angle spectrometer at the CERN-ISR - a brief description of the experimental arrangement and of the procedures for data acquisition and analysis, LUSY 7210 (The British-Scandinavian ISR Collaboration)
21. Inclusive particle production at large angles measured at the CERN ISR, The 4th International Conf. on High Energy Collisions, Oxford 1972 (The British-Scandinavian ISR-Collaboration)

22. Inclusive particle production in the rapidity range 0 to 1 at the CERN ISR, The 16th International Conference on High Energy Physics, Batavia 1972 (The British-Scandinavian ISR-Collaboration)
23. The study of particle correlations at large angles using the split field magnet, CERN-ISRC 71-38, CERN-ISRC 71-38, add.1. (Scandinavian Collaboration)
24. Study of particle correlations at large angles at the ISR, using the split field magnet, CERN-ISRC 72-7, CERN-ISRC 72-7, add.1. (MIT-Orsay-Scandinavian Collaboration)

I.

Although most of the medium high energy phenomena in the photoproduction of pions are qualitatively well determined it is still essential to improve the quality of data, especially polarization data, in a systematic way, which usually means high statistics and flexible apparatus. It is therefore most useful to develop a means of rapid and automatic data collection. In 1964 Professor Guy von Dardel proposed the construction of a vidicon system which could automatically record events from an optical spark chamber system either on-line to a computer or off-line on magnetic tape.

This vidicon system was developed at CERN in stages leading to several prototype systems which are described in papers 1-4 and ref. 1 (here detailed electronics schemes are presented). Much effort was spent in designing an efficient hard-ware guided scan. It was tested in a measurement of the asymmetry parameter in Λ^0 -decay, 1966 (ref.2). It was the intention to use the vidicon system in Lund for the (high statistics) measurement of the polarization of recoil photons in the photo-production of neutral pi-mesons off hydrogen.

When the Lund electron synchrotron was constructed the technical complexity of this project took nearly all available resources of the small physics department at the Lund University into account and rather little could be done in planning for the use of this instrument. The experimental program was severely hampered by this and although the support to experiments gradually increased, the first few years of physics preparation were extremely difficult. This fact is reflected in many of the reports included in this and the following (II.) experiments. The level of ambition had to be lowered several times.

The program of the π^0 experiment as of 1966 is outlined in ref. 3. Here the plans were quite elaborate using a beam of polarized photons with polarization analysis of the recoil protons using scattering off carbon in an optical spark chamber and collecting data using the vidicon system connected on-line to a computer. The program was redefined in paper 5 (1968) to include a measurement of the differential cross section prior to the polarization studies of the recoil proton (using a normal Bremsstrahlung beam). The experiment in progress still follows this plan.

The development of other parts of the experiment was later given priority over finalizing the vidicon system in order to get the first part of the experiment under way. Papers 6-8 is an account of some of the apparatus which had to be built for the experiment. Practically all components of the apparatus had to be designed and built at the laboratory. The solutions chosen were frequently not very sophisticated but inexpensive and adequate. The results of the first part of the π^0 experiment, namely on the differential cross section in the range of 580-685 MeV for the energy of the incoming photons, are presented in paper 9.

II.

The preparation for the second experiment started in 1963 with the design of an acoustic spark chamber system which was initially meant to be a generally useful detector system for the laboratory. This development was temporarily inhibited by the work on the vidicon system mentioned above but a prototype system was completed and working in 1967 as described in paper 10. Later a scaler-computer interface was built that allowed the on-line transfer of data to the IBM 1800 of the laboratory (paper 11). It was foreseen that the sonic spark chamber system should be used with a pair spectrometer. However, due to lack of resources we had to set up a simpler system, using conventional

counter telescopes. In paper 12 some preliminary results from this pair spectrometer are presented. We have made a specially careful study of the effects of a thick target and collimation on the Bremsstrahlung beam. The final results are to be presented by my collaborators.

III.

During the measurements using the pair spectrometer some tests on small angle photon scattering were made in order to investigate a possible extended use for this instrument and the sonic spark chamber system. These investigations, which were originally apparatus oriented, led to the "rediscovery" of the Delbrück scattering process which had so far not been studied using high energy photons. Being a fundamental process of quantum electrodynamics this seemed extraordinary interesting and led us to propose such an experiment for the 7.5 GeV electron synchrotron at Hamburg in collaboration with a DESY team (paper 13). The experiment could not easily have been done in Lund with the beam conditions and the support available there. The experiment in DESY is now completed. A Monte Carlo program for the simulation of all kinds of expected events was prepared in Lund (ref. 4). One of the subroutines of this program, generating multiple scattering, is now included in the CERN scientific program library (paper 14). The technical details of the experiment are given in paper 15. The results of the analysis are presented in paper 16. The data analysis led us to the identification of the predicted but so far undetected process of photon splitting. Our results on the Delbrück scattering process differed from the theoretical prediction of Cheng and Wu (ref. 5) with a factor 3-5 and spurred them to recalculate the process now taking higher order Coulomb corrections into account. It appeared that the inclusion of Coulomb corrections to the 12th order in α could fully account for the large discrepancy found (ref. 6).

IV.

Before the existence of super high energy accelerators our only knowledge of high energy processes came from cosmic ray experiments. Paper 17 gives a brief summary of our knowledge of high energy processes from cosmic ray physics as of 1969. As the accelerator energies have increased we have approached the cosmic ray physics region. The definite step into that region was the completion of the CERN intersecting storage rings. This instrument, which has been used in the experiment IV, has increased the previously available reaction energy by one order of magnitude. It has been available for physics a little more than one year. A rather detailed description of the ISR is given in Kosmos 1971 (ref. 7).

I was involved in the early planning of this experiment (Bergen 1969) and in the drafting of the proposals for the CERN ISRC (papers 18-19). The experimental aim is to survey particle production (one particle inclusive study) in proton-proton collisions at large angles and to search for new heavy particles (quarks) which might be produced at the extremely high energies (56 GeV in the centre of mass) available with the colliding beams at the ISR. The apparatus used for this purpose and the methods of data collection and analysis are described in paper 20 and the first results obtained (for the lower momentum region) are presented in papers 21 and 22. Result on inclusive particle production over an angular range of 29° to 90° in the centre of mass are given. It has been found that for some of the particles produced ($\pi^{\pm}$) an asymptotic behaviour of the cross section has already set in (i.e. the cross section is independent of incident energy), while for other particles ($K^{\pm}$ $p\bar{p}$) the asymptotic behaviour is approaching more slowly. The experiment will continue during 1972-73 and will be followed up by a study of two-particle correlations using a large magnet detector surrounding one of the intersection regions (the SFM magnet). Our proposal for this new experiment (approved 1971) is given in paper 23 and in paper 24 our latest plans are defined.

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